

The impact of rise of the Andes and Amazon landscape evolution on diversification of lowland *terra-firme* forest birds

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Since the 19th Century, the unmatched biological diversity of Amazonia has stimulated a diverse set of hypotheses accounting for patterns of species diversity and distribution in mega-diverse tropical environments. Unfortunately, the evidence supporting particular hypotheses to date is at best described as ambiguous, and no generalizations have emerged yet, mostly due to the lack of comprehensive comparative phylogeographic studies with thorough trans-Amazonian sampling of lineages. Here we report on spatial and temporal patterns of diversification estimated from mitochondrial gene trees for 31 lineages of birds associated with upland *terra-firme* forest, the dominant habitat in modern lowland Amazonia. The results confirm the pervasive role of Amazonian rivers as primary barriers separating sister lineages of birds, and a protracted spatio-temporal pattern of diversification, with a gradual reduction of earlier (1st and 2nd) and older (> 2 mya) splits associated with each lineage *in an eastward direction*. (The easternmost tributaries of the Amazon, the Xingu and Tocantins Rivers, are not associated with any splits older than > 2 mya). For the suboscine passerines, maximum-likelihood estimates of rates of diversification point to an overall constant rate over the past 5 my (up to a significant downturn at 300,000 y ago). This “younging-eastward” pattern may have an abiotic explanation related to landscape evolution. Triggered by a new pulse of Andean uplift, it has been proposed that modern Amazon basin landscapes may have evolved successively eastward, away from the mountain chain, starting ~10 mya. This process was likely based on the deposition of vast fluvial sediment masses, known as megafans, that may have extended progressively and in series eastward from Andean sources. This process plausibly explains the progressive extinction of original Pebas wetland of western-central Amazonia by the present fluvial landsurfaces of a more *terra-firme* type. The youngest landsurfaces thus lie furthest from the mountains. In this scenario major drainages were also reoriented in wholesale fashion away from a northerly orientation generally towards the east and an Atlantic Ocean outlet. The advance of megafans is best seen by the location of axial rivers such as the Orinoco and Mamore which lie against the cratonic margins furthest from the Andes, at the distal ends of major megafan ramparts. More importantly, other major river courses in western-central Amazonia will have been established at progressively younger dates with distance eastward. If this landscape-sequence scenario is accurate, it parallels the progressive younging of the passerine lineages. The bird DNA data appears to confirm strongly the pervasive role of Amazonian rivers—as primary barriers separating sister lineages of birds, and thus probably as facilitators of bird speciation. We show for the first time that a general spatio-temporal pattern of diversification for *terra-firme* lineages in the Amazon is associated with rivers (“younging-eastward”), and furthermore parallels a specific scenario of regional drainage evolution.
